

Müller's investigations indicate that a greatly diminished splitting up of the ingested fat *per se* positively indicates the absence of pancreatic juice in the intestinal digestion. In this case, therefore, in the absence of a cachexia or other signs of a neoplasm of the pancreas or of neighboring organs which would occlude the ducts by pressure, a pancreatic lithiasis should be suspected.

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WOLFF'S LAW AND THE FUNCTIONAL PATHOGENESIS OF DEFORMITY.*

BY ALBERT H. FREIBERG, M.D.,

OF CINCINNATI, OHIO,

PROFESSOR OF ORTHOPEDIC SURGERY, MEDICAL COLLEGE OF OHIO, MEDICAL DEPARTMENT
OF THE UNIVERSITY OF CINCINNATI.

THE correspondence between the structure of bone, under normal and abnormal conditions, and the calculations of graphic statics has been made the foundation upon which a doctrine of "functional pathogenesis" has been built. It has, however, formed also the basis of numerous attacks upon this theory. The theory of the functional pathogenesis of deformity and that of the functional shape of the bones have been made corollaries to the "law of bone transformation" by its author, Jul. Wolff. The "law of bone transformation" is considered by its author as deriving its greatest strength from the remarkable resemblance existing between the internal structure of the normal human femur and the graphostatic diagram of a Fairbairn crane drawn by the mathematician Cullmann. This was given an outline similar to that of the human femur deprived of its trochanter major and viewed in coronal section, sustaining a load of 30 kilogrammes. This load is supposed to approximate that which is borne by the femur of an adult and to be applied to the crane in a manner consistent with the conditions in the human subject. The striking analogy

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between the courses of the bone trabeculae in the frontal section of the femur and those of the trajectories of Cullmann's diagram was first insisted upon by von Meyer. The arrangement of the spongiosa in the sagittal section of the femur, corresponding to the "neutral plane" of the diagram, was foretold by Wolff in conformity with the demands of the graphostatic figure, and was substantiated by him later, anatomically. After the most painstaking study of the various bones of the body under normal and abnormal conditions Wolff was able to formulate his "law," which might be translated as follows:

"Every change in the form and function of the bones, or of their function alone, is followed by certain definite changes in their internal architecture, and equally definite secondary alterations of their external conformation, in accordance with mathematical laws."

Before the promulgation of Wolff's law the generally accepted theory of the development of acquired deformity was that of Volkmann-Hueter,⁷ namely, that consequent upon muscular weakness faulty attitude was assumed, in consequence of which one side of a joint—*e. g.*, the external in genu valgum—was subjected to greater pressure than normal; the opposite side—the internal in genu valgum—sustained less pressure than normal. Assuming that during growth the normal development of the joint depends upon the maintenance of normal conditions of intra-articular pressure, it was explained that the increased pressure on the concave side interfered with the normal growth of bone or even caused atrophy of that bone already formed; while on the convex (internal) side the subnormal pressure permitted an overgrowth of bone. In spite of the fact that Mikulicz⁴ and Macewen⁵ showed, quite long ago, that these changes in the articular surfaces and epiphyses are not constantly present in genu valgum, but that the principal deformity exists in the diaphyses of the femur and tibia, most authors continued, nevertheless, to describe the pathogenesis of this deformity in conformity with the theory of Volkmann-Hueter. We shall later see how it is better explained by reference to Wolff's law and in agreement with the anatomical conditions present.

The first corollary which Wolff's theory has associated with it is that of the "functional shape." The external form and internal architecture are determined by function solely. The internal architecture and external contour always correspond exactly, the latter representing, mathematically, simply the last curve uniting the ends of the various trajectories which make up the internal structure. The compact substance is to be regarded simply as a condensation of spongiosa.

From the theory of the "functional shape" it is an easy step to that of the "functional pathogenesis" of deformity. If the internal structure and external contour correspond exactly, and if they represent an adaptation to normal function only, then an alteration in static

demands made upon the bones must be followed by the proper transformations of structure, both internal and external, and as the result of these we have the "deformity in the narrower sense." The deformity is therefore to be regarded as a physiological adaptation of structure to pathological static requirements, therefore to pathological function.

The agreement of the structure of bone, both under normal and abnormal circumstances, with mathematical laws, and in particular with those of graphic statics, is insisted upon by Wolff to such an extent that it has formed the basis of attacks upon the doctrine by Bähr' and Ghillini,' as well as others. It is their object to show that Wolff's mathematical conclusions are erroneous, and that therefore it is not permissible to make deductions from them regarding the structure of the bones in their normal or pathological relations.

We may well ask ourselves, on this account, whether mathematical proof of the competency of nature's design in bone structure has been brought by Wolff in Cullmann's drawing of the Fairbairn crane and the deductions following. What is required to enable us to construct the graphostatic diagram of the femur? It must be understood, as a preliminary in answering this question, that when "mathematical proof" is spoken of mathematical accuracy is implied. It is by no means enough to say that a striking similarity exists between the diagram and the bone whose mechanics we are trying to solve. There must be absolutely no divergence between the two.

In order that the mechanics of the femur shall be submitted to mathematical proof, we must know every possible stress to which the bone is to be submitted under normal conditions, and these stresses must be expressed in figures. There must be possible of expression in figures the physical characteristics of the material used in the structure. But bones are evidently constructed of sufficient strength to withstand unusual stress without giving way. This fact is demonstrated in every-day life. How shall we calculate this "factor of safety." We may believe, with Wolff, that the femur is burdened like a crane, or with his opponents that this is not so; but the fact remains that Cullmann's diagram is computed without mention of the muscular stresses upon the bone—without reckoning with the stresses put upon the bones in other positions than the upright. The great trochanter has been omitted from consideration altogether. This is obviously not permissible in a mathematical calculation, because it is always present, because it is the means of transmitting very considerable stress to the femur, and because its internal structure is evidently continuous with that of the upper end of the femur. I am assured by experts that the proper calculation of the construction of the femur upon exact mathematical lines is a work of great magnitude, requiring not only uncommon ability, but, on account of the enormous complexity of the problem,

demanding a very large expenditure of time. To my knowledge, no such exact mathematical demonstration has yet been made. In addition to this, it is by no means certain that the "factor of safety" could be calculated; this factor might well make the mathematical solution impossible. Until exact mathematical proof is brought, however, there would seem to be no warrant for saying thus definitely that the external contour of a bone represents mathematically the last curve uniting the ends of the various trajectories which make up the internal structure—for assuming that the compact substance is to be regarded simply as a consolidation of those trajectories coming from the spongiosa.

If we are unprepared, however, to acknowledge that a truly mathematical demonstration of the structure of the bones has been made, we are, on the other hand, entirely unwilling to reject the law of transformation and its corollaries on this account without further investigation. In declining to accept the analogy between Cullmann's diagram and the structure of the femur as a truly mathematical demonstration of the latter, we are, furthermore, far from saying that if such computation and graphostatic figure were made it would not coincide with the architecture of the bone. On the contrary, the structure of the femur having been shown by many years of observation to be constant, the similarity between it and the mathematical figure is so striking as to make it seem reasonably certain that the trabeculae do represent lines of force which nature aims to resist by the laying down of the bone tissue. This is, however, far from being mathematical proof, and, as it seems to us, does not afford justification for considering some of Wolff's other conclusions as "mathematical," however true they may be otherwise shown to be.

In view of the necessarily great variation in the factors of weight-bearing and muscular stresses which must exist in mammals other than man—because of the deviation from the erect position of the trunk and because of the participation of the thoracic extremities in the weight-bearing function, it would seem likely that much information could be obtained from the study of their bones. Able and exhaustive investigation has already been made in this direction by Zschokke,¹⁰ Schmidt,¹¹ and others. It has seemed worth while to independently repeat some of this work as well as to seek further for information in the structure of other mammalian bones. The femur has been chosen as the bone for further comparison, because of its size and static importance and because it has formed the basis for most of the conclusions which have already been drawn. In examining the femora to be presently described the method reported by Wolff⁸ was employed. Sections were cut by hand by means of a saw. These sections were then photographed by means of the Röntgen ray, and from the nega-

tives thus obtained the photographs were made which are herewith presented. As is the case with many radiographs, the negative is more instructive than the print made from it. In the smaller femora it was quite difficult to obtain prints the finer details of which would lend themselves to satisfactory reproduction.

In the description of the specimens which have been examined care has been taken to avoid as much as possible the repetition of details which coincide with the descriptions of Zschokke and Schmidt, above referred to. The following femora have been examined:

- I. Ruminantia.
 - (a) Ox.
 - (b) Llama.
 - (c) Sheep.
- II. Carnivora.
 - (a) South African leopard.
- III. Primates.
 - (a) Baboon (*papio hamadryas*).
 - (b) Orang (*simia satyrus*).
 - (c) Gibbon (*hylobates*).

(Humerus of gibbon also.)

For the privilege of examining into the architecture of the femora of the orang and gibbon, as well as the humerus of the latter, I wish to acknowledge my indebtedness to the administration of the Smithsonian Institution. Many of the other bones examined have been taken from the museum of the Cincinnati Society of Natural History.

REMARKS ON THE SPECIMENS EXAMINED.

I. RUMINANTIA. (a) *Femur of the Steer.* (Fig. 1.)

Relative length of the neck is short. Capital epiphysis extends laterally to a point corresponding practically with the axis of the shaft. It is covered with cartilage to this point, and is to this extent a bearing surface. The angle made by the neck is about 112° .

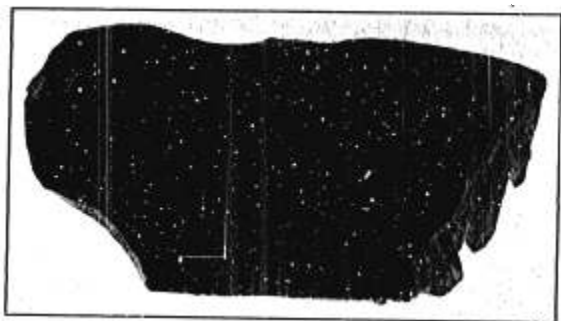
Arrangement of trabeculae is perfectly constant, and corresponds with the description of Zschokke and Schmidt. The spongiosa of the young adult is composed of exceedingly fine trabeculae. As the age increases the trabeculae become coarser and less numerous, so that the internal structure is more easily read. In old animals this change has continued, so that the difference between their spongiosa and that of the young animal is most striking (see Zschokke). The three most striking systems of trabeculae seen are:

1. *Principal pressure trajectories* (converging from the mesial part of the head to the adductor compacta).

2. *Trabeculae from adductor and abductor compacta arch toward the axis of the bones, forming a series of gothic arches whose apices*

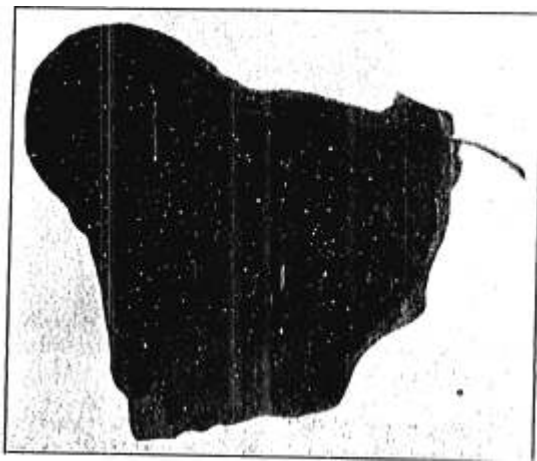
are in a straight line with the lateral boundary of the capital epiphysis. Such a series of arches also exists in the trochanteric epiphysis. Orthogonal crossings can be distinguished in the system of arches.

FIG. 1.



Femur of young adult steer.

FIG. 2.



Femur of llama.

(b) Femur of the llama. (Fig. 2.)

There is practically no neck to the bone. Capital epiphysis extends to the axis of the shaft, as in the steer, but the head is set more obliquely, making an angle of 120° with the shaft.

Although the animal is comparatively young (shown by imperfect union of epiphysis), the trabeculae are comparatively coarse, their meshes large. The arrangement of gothic arches is lacking.

The marrow cavity extends comparatively high into the upper end of the bone. There are three systems of trabeculae:

1. Principal pressure trabeculae.
2. Two systems diverging from the base of the great trochanter.
 - (a) Toward the head.
 - (b) Downward to the abductor compacta.

(c) Femur of the Sheep. (Fig. 3.)

In general shape and plan of internal structure we have the steer's femur in miniature. The angle of the neck is somewhat greater (115°

FIG. 3.



Sheep.

to 117°), otherwise the same arrangement of capital epiphysis and gothic arches, though sometimes not so easily made out. Orthogonal crossings can in part be distinguished.

II. CARNIVORA. (Fig. 4.)

The only specimen examined was the femur of a South African leopard. The femur is characterized by its proportionately long,

slender, and somewhat curved neck, which makes an angle of 130° with the shaft. The spongiosa is made of plates.

The femoral neck presents a triangular cavity of considerable size,

FIG. 4.



Leopard.

and which in position and boundaries would correspond with Ward's triangle of the human femur. This is separated from the marrow cavity below by a small number of arches coming from the adductor

FIG. 5.



Baboon.

compacta and corresponding to pressure trajectories. The crossings here are orthogonal.

Shorn of the trochanter major the outline is very like that of Cullmann's diagram; the internal arrangement is, however, very different.

III. PRIMATES. (a) *Femur of Arabian Baboon (Papio Hamadryas).*
(Fig. 5.)

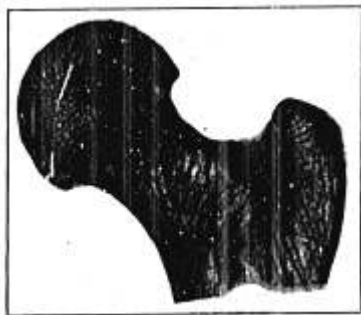
The bone is remarkably heavy for its size, and of very dense texture, so that it is difficult to saw. The neck is curved, and makes an angle of about 124° .

The trabeculae are massive, largely in the form of plates. In the head they are fairly typical as principal pressure trabeculae, and here show orthogonal crossings, with a few tension plates. There is here, too, a cavity in the neck, separated by a few plates only from the cavity of the shaft below. The compacta of the shaft is relatively very heavy and thick, so that it is difficult to bring it into comparison with the amount of spongiosa.

(b) *Orang.* (Fig. 6.)

Both in external conformation and internal structure the upper femoral end is strikingly like the human. The angle made by the

FIG. 6.



Orang.

femoral neck is 135° . Both pressure and tension trajectories are found projected in a fairly typical manner, though the reticulum is much coarser than in man, the trabeculae more plate-like. Orthogonal crossings can be made out to a limited extent. The condensation of spongiosa known as the "intermediary epiphyseal disk" (Recklinghausen), and which is constant in the adult femur, is lacking.

(c) *Gibbon.* (Fig. 7.)

In general outline the upper femoral end greatly resembles that of the orang and man. The bone is remarkably light, however, its shaft

very smooth and round, reminding one very forcibly of the bones of larger birds. This comparison seems all the more apt upon bisecting the bone, because of the relatively large marrow cavity, with no spongy structure whatever save at the extreme ends. The angle of the neck is 140° .

The section shows a spongiosa of lamellar character, in which it is extremely difficult, if at all possible, to find an arrangement in any way similar to that of man or, indeed, of any of the femora previously described. The neck proper is practically free from spongy structure, a cavity being here found which extends to the spongiosa of the head above and to that at the base of the great trochanter below. The cellular spaces of the spongiosa are relatively very large.

In view of the contrast in functional importance between the femur and the humerus in the gibbon, great interest must attend the com-

FIG. 7.



Femur of gibbon.

FIG. 8.



Humerus of gibbon.

parison of their internal structures. The result of it is in accord with our anticipation. The internal structure consists of a lamellar spongiosa of comparatively coarse mesh, but in its general arrangement strikingly that of the human humerus. This is true even to the existence of a place near the great tuberosity in which the spongiosa is quite rare, almost to the degree of being considered a cavity. The remains of the epiphyseal line correspond both in direction and position, and the outline is simply a miniature of the human. (Fig. 8.)

In addition, it is to be noted that the gibbon's humerus is, in comparison with its femur, heavier and denser. On holding the bones close to a bright light the shaft of the femur is seen to be quite translucent; that of the humerus is not at all so. While the humerus is a longer bone, its density is disproportionately greater than that of the femur. The volume of the two bones was determined by ascertaining their displacement of water. This was found to be 25 c.c. for the humerus

and 22 c.c. for the femur. The weight of the humerus was 30.45 grammes against 21.67 grammes for the femur. Their ratio of weight is therefore 1.405, while their ratio of volume is 1.045. It is easily seen that the humerus is an organ of greater strength and usefulness than the femur.

In making a general comparison of the specimens in hand, it is well to remember that in graphic statics:

1. The courses of the various trajectories are dependent upon the external shape of the structures, and conversely,

2. The number of the trajectories and their size depend upon the varying factors of weight and the character of the material.

It was remarked by Zschokke—and the statement is to day equally true—that it was not possible to estimate the stresses in bone more than approximately up to that time, but that it was necessary as a matter of scientific reasoning to show, at least in some bones, that the trabeculae truly correspond to the trajectories in direction and strength. Ten years have elapsed since this was written, but the task has not yet been performed.

Bähr, Ghillini, and the latter in co-operation with Canevazzi, have offered certain calculations in opposition, but these by no means present the solution which we seek. It would appear, therefore, that we are not yet provided with exact data to attempt a truly mathematical solution of the mechanics of the femur. If we cling too closely to the mathematical concept of bone structure we shall find it impossible, for example, to reconcile the structures in the upper femoral ends of the gibbon and the orang. We have here a striking similarity of outline, with an equally marked incongruity of internal formation.

If, however, we depart from the strictly mathematical notion and examine into the environment and habits of the gibbon and orang we shall find an admirable adaptation of structure to these and an explanation of the great variation in internal structure. According to Flower and Lydekker,* the gibbon is by nature an arboreal creature of great lightness, accustomed to maintain itself almost entirely by the thoracic extremities. Its movements are extremely rapid, and it is able to project its body through long distances in space in swinging from bough to bough and from tree to tree. When pursued on the ground and unable to reach a tree it moves forward chiefly on its pelvic extremities, and practically in the upright position, but so awkwardly and uncertainly that it is easily overtaken by man. The humerus of the gibbon, however, belongs to the extremity of greater power and use, and is manifestly of corresponding build. In the orang, on the other hand, we find great muscular power in the posterior extremities

and comparative slowness in movement. We may similarly compare the femora of the leopard and the baboon, although possibly not so aptly, the former possessing wonderful agility and ability to make enormous leaps, the latter being contrasted by the great muscular development in proportion to its size. According to Zschokke, the femora of bears able and accustomed to maintain themselves frequently in the upright position possess great resemblance to the human in their structure. So in the ruminants, also, we find the modifications of internal structure in accordance with the shortness of the femoral neck, adapted, as this is, to weight-bearing purely rather than a large range of motion.

From the above we should be justified in concluding that while external conformation and internal structure represent admirable adaptation to use, their mutual interdependence is not so exact as the strictly mathematical concept would require. If we are to modify the doctrine of the functional shape of the bones to this extent, it is probable that the doctrine of functional pathogenesis must likewise be qualified.

Valuable evidence for the theory of functional pathogenesis should be found where the function of a bone has been changed for a considerable time without any gross solution of its continuity. It is believed that such evidence can be found in the specimen of old unreduced dislocation of the hip which is next presented, and in which we have the advantage of comparison with the normal femur of the same individual.

Description of Specimen of Old Unreduced Dislocation of the Hip, from the Museum of the Cincinnati Hospital (Series VII., No. 127 f).

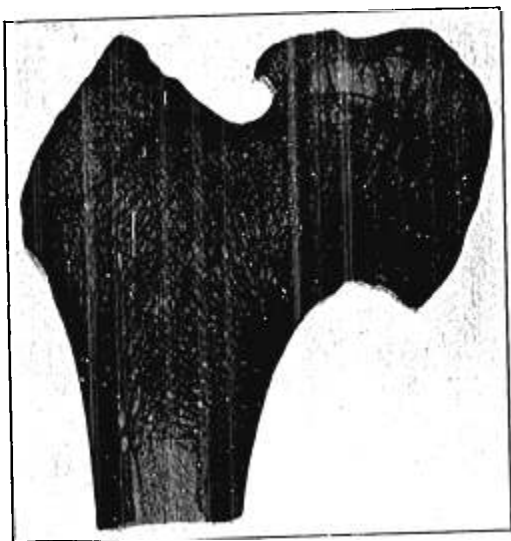
The specimen has been in the Museum for many years, and all clue to the history of the case has been lost. The board has wired upon it:

The Os Innominatum of the Side of the Luxation. This shows the acetabulum to have been unoccupied by the femoral head for a long time. The floor has become roughened by the presence of small osteophytes. The acetabular cavity appears to have become smaller by the thickening of its rim and the formation of new bone in its floor. Just behind the acetabulum there is seen a rather flat, though slightly concave, bone mass of roundish outline, with a diameter of 5 to 3.5 cm., and elevated 0.52 to 0.53 cm. above the surface of the surrounding bone. This rests upon a buttress of bone thrown out from the ilium and ischium. It is evidently the representation of an attempt at forming a new acetabulum.

The Upper End of the Right (Dislocated) Femur. (Fig. 9.) This has been sawed through about 8 cm. below the tip of the great trochanter. It has also been bisected in coronal section.

The Upper End of the Left Femur (Normal). (Fig. 10.) This has been sawed through at 6.7 cm. below the tip of the great trochanter, the cut just striking the tip of the lesser trochanter. It has also been bisected in coronal section. Upon joining the halves of the right (luxated) femur and attempting to fit the head, in its dislocated position, into the new acetabulum, it is readily seen that its superior surface—that which formerly was the chief means of transmitting weight—was no longer a bearing surface, but that the joint bearing under the new conditions

FIG. 9.



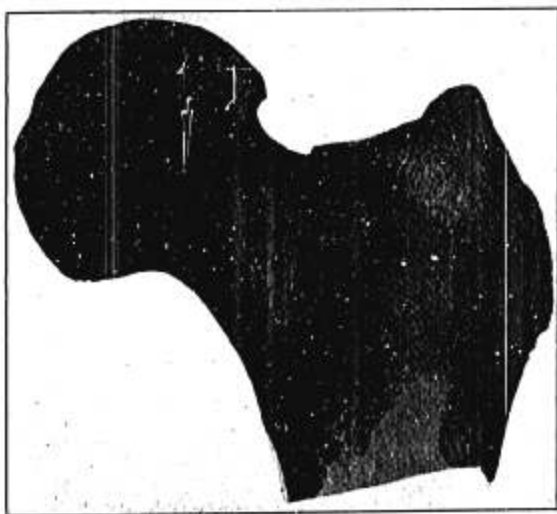
Dislocated femur.

was displaced downward. It can be seen that the position of the femur could not have been maintained by the bony socket alone, but that the soft parts must have played an important if not the chief rôle in this.

The examination of the femoral head shows at once that it may be divided, functionally, into an anterior and posterior, an upper and lower segment. The anterior segment is characterized by the smoothness of its external contour and its roundness when compared with the posterior segment, which is rough, presenting irregular elevations. The

margin of the head in the posterior segment is considerably mushroomed; this is not so in the anterior. The corticalis of the posterior segment is very thin, and in one place has disappeared, so that the spongiosa is exposed. (This is not broken.) The head is no longer nearly spherical, but bullet-shaped, with a rounded apex in the line of the cervical axis. Crossing the anterior segment is a slight ridge which divides the anterior segment into an upper and lower portion. The upper portion is somewhat rougher and flatter than the lower, and this division will be later referred to in the description of the section.

FIG. 10.



Normal femur from same subject.

From the anterior half of this femur a section was cut varying from 3 to 4 mm. in thickness. A similar section was taken from the left femur. Through a mishap the spongy portion in the lower portion of this section was broken. The spongy tissue should be intact through the section. The following measurements show in part the decided differences existing between the right and left femurs: Diameter from the circumference of the head to the base of trochanter major: right, 8.75 cm.; left, 10.40 cm. Height of trochanter major from tip to base: right, 4 cm.; left, 4.46 cm. Greatest thickness of adductor compacta: right,

0.58 cm.; left, 0.44 cm. Greatest thickness of abductor compacta: right, 0.57 cm.; left, 0.34 cm. Angle between the neck and shaft: right, 122° ; left, 127° .

The following changes of external configuration may therefore be noted: (a) General diminution in the size of the bone; (b) diminution of the angle between the shaft and the neck; (c) alterations in the shape of the femoral head, as before described.

The transmutations of the internal structure are, however, more striking, and when taken in conjunction with the above-mentioned alterations of external contour, and in view of the changed conditions of stress from both weight-bearing and muscular action, make it possible for us to present a rational interpretation. These transmutations may be described as follows:

1. The cancellous tissue is of looser mesh than that of the left femur.

2. The tension trabeculae proceeding from the abductor side are shorter in length, but also of changed (shortened) radii. The pressure trabeculae, however, seem, if anything, more numerous and of greater strength than those of the left femur. As the result of this, Ward's triangle, which is ordinarily constituted by the convergence of two well-defined groups of trabeculae coming from the upper part of the head and region of the great trochanter, respectively, has disappeared entirely.

3. The most conspicuous change of the internal composition is, however, to be observed in the head. We have here a considerable cavity in the spongy tissue, corresponding in position to the flattened part of the head, and which is traversed by a few bone plates. The antero-posterior depth of this cavity is 2.50 cm.; its width in the coronal section is 2 cm. The antero-posterior diameter of the head at this part is 3.40 cm. The floor of this cavity corresponds exactly with that ridge on the anterior aspect of the head which divides this into an upper and lower segment.

4. Upon examining the anterior and posterior halves of the bone, it is seen that the cancellous arrangement in the anterior segment is more compact.

Unfortunate as it is for the present inquiry that no record is left to show the exact amount of motion and strength possessed by this dislocated hip, the changes of its structure nevertheless correspond strikingly with the requirements of Wolff's law. The atrophy of the unused parts, and the condensation of those bearing increased stress, as well as the decided change of external conformation, are sufficiently manifest as to impossibly escape notice. Equally evident, however, are the encroachment upon the original size of the acetabular cavity by the formation of new bone, and the irregular surface of the unused part of the femoral head for the same reason. I take it that we have here conditions

analogous to the so-called hypertrophy of the inner condyle in genu valgum, and that we are dealing with an increase in cubical dimensions as an accommodation to altered conditions of space. If this increase of cubical dimensions is to be so regarded it must be looked upon as a result of the deformity and not as one of its causes. Its functional rôle in resisting stress can, from its physical characters, be considered insignificant.

From the researches of Wolff, Zschokke, Schmidt, and others, as well as from the observations herewith presented, it is believed justifiable to conclude as follows:

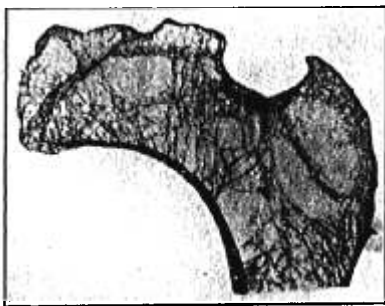
1. The strictly mathematical concept of Wolff's law has not yet been justified by demonstration.

2. Save in their mathematical aspects, the statements of Wolff's law and its corollaries may be accepted as being in agreement with observations hitherto made.

3. If we accept the foregoing statements it does not follow that we must make use of the so-called "functional methods" in our therapeutic endeavors; they are to be chosen not from theoretical considerations only, but for reasons of expediency and practicability.

[NOTE.--In the discussion following the reading of this paper there was presented the right femur of an idiotic woman, thirty-five years

FIG. 11.



Section of femoral head of a paralytic idiot, aged thirty-five years.
(By permission of Dr. R. T. Taylor.)

of age, by Dr. R. Tunstall Taylor, of Baltimore. The specimen is of such interest, and is believed to be corroborative to such a degree, that, with Dr. Taylor's kind permission, the case and section of the bone are herewith briefly presented. The subject from whom it came was

a paralytic, considerably deformed, having severe scoliosis and being greatly underdeveloped. The fibula of this subject was about fifteen inches long and somewhat greater in thickness than a good-sized knitting-needle. The pelvis was likewise deformed. The femur is extremely light in weight. Its extreme length is 38 cm.; the coronal diameter of the shaft at the middle is 1.3 cm. The head is greatly flattened from above downward, as may be seen from the section. The surface is marked by several deep grooves of antero-posterior direction. Otherwise the bone is of fairly normal shape, with the exception of the trochanter minor, which forms a quite long spur projecting anteriorly, leaving a deep groove between it and the upper part of the shaft. The radiogram of the section of the upper extremity of this femur is almost self-explanatory. (Fig. 11.) Vestiges of the normal internal structure are apparent. Such are the intermediary epiphyseal disk, some of the principal pressure trajectories, and some of the arches as well. The upper end of the bone is, however, merely a hollow shell, and expressive, it seems to me, not only of imperfect development, but of general atrophy also. As far as can be ascertained, this person was never able to maintain the upright position.]

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A DISCUSSION OF WOLFF'S LAW.¹

BY R. TUNSTALL TAYLOR, B.A., M.D.,

SURGEON-IN-CHARGE OF THE HOSPITAL FOR CRIPPLED CHILDREN; CLINICAL PROFESSOR OF ORTHOPEDIC SURGERY, UNIVERSITY OF MARYLAND; ORTHOPEDIC SURGEON TO THE UNIVERSITY HOSPITAL, BALTIMORE; FELLOW OF THE AMERICAN ORTHOPEDIC ASSOCIATION, ETC.

WE should feel much indebted to Dr. Freiberg for bringing the subject of Wolff's law, with its subordinate corollaries, before this Association, if for no other purpose than to promote a discussion of the thoroughness of its proof and its apparent impregnability.

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